# The Process and Mechanism of *Solanum Rostratum*

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**Abstract: Invasive plants are an important group of invasive alien organisms, and their invasion will lead to the loss of ecosystem diversity, species diversity, and diversity of biogenetic resources, resulting in serious economic losses. Invasive alien plants are plants that have overcome abiotic and biotic barriers to survival, are capable of reproducing and sustaining populations without direct human intervention, and have broken through barriers to dispersal to form self-sustaining populations in areas far from the site of introduction. It is an annual herbaceous plant of the Solanaceae family, and is a highly invasive and vicious weed. It not only destroys the ecological balance, affects the survival of local species, and threatens biodiversity, but also may become the source of new diseases, which is a direct threat to human health, so the study of the invasion process of the *Solanum rostratum* prickly pear and its invasive mechanism is of great significance. We summarize the progress of research on the invasion mechanism of *Solanum rostratum* eggplant at home and abroad, and analyze the adaptation and dispersal mechanisms of *Solanum rostratum* eggplant. We also review and analyze the mechanisms by which S*olanum rostratum* eggplant successfully settles in new environments as an invasive species from the perspective of its own reproduction, seed dormancy, genetic properties, seed dispersal, chemosensitization, competition, and eradication, and describe the adaptive evolution, coordinated invasion, and invasion mechanism of *Solanum rostratum* eggplant. It also describes the adaptive evolution, collaborative invasion, and pollination effects of A. flavus. On this basis, we will prepare for further research on the control of *Solanum rostratum*.**

**Keywords: Alien Species; *Solanum Rostratum*; Invasive Species; Invasion Mechanism; Diffusion Mechanism**

## 1. Introduction

*Solanum rostratum* is native to North America, but is now also found in Canada, Russia, Korea, Bangladesh, Australia, Austria, Bulgaria, the Czech Republic, Slovakia, Germany, Denmark, South Africa and New Zealand. *Solanum rostratum* is an annual herbaceous plant, and seed dispersal is the primary means of its rapid spread. It was first introduced to China in the 1980s in Chaoyang City, Liaoning Province, and subsequently spread to Fuxin, Jianping, and Dalian [1,2]. Later, it was discovered in Baicheng, Jilin Province; Zhangjiakou, Wanquan, Hebei Province; Miyun, Yanqing, and Mentougou, Beijing; Yanggao, Shanxi Province; and Urumqi and Changji, Xinjiang [3-4]. In 2020, it was also detected in Songyuan City, Jilin Province.

Alien invasive plants are plants that have overcome abiotic and biotic barriers to survival, are able to reproduce and maintain populations without direct human intervention, and further break through dispersal barriers to form self-sustaining populations in areas far from the point of introduction [5]. In recent years, with the increasing trade activities and continuous improvement of transportation infrastructure in China, the risk of plant invasions has been growing significantly. Invasive alien plants often exhibit high environmental adaptability in new habitats, resulting in delayed prevention and control efforts. Due to their characteristics of rapid spread, fast growth, and strong adaptability [6-8], the prevention and eradication of invasive alien plants have become a persistent challenge and critical issue in ecological conservation across various regions.

## 2. The Invasion Mechanism of *Solanum Rostratum*

Generally, the invasion process of plant species can be divided into three stages. The first step in the successful invasion of a species is its

 

introduction through three main routes, namely, unintentional introductions based on human activities, such as transportation, trade in commodities, tourism, and so on. Conscious introductions such as seed introduction and resource exchanges, and natural introductions such as migration, air currents and water currents [9].

The *Solanum rostratum* has a strong ability to reproduce and spread, attaching itself to animal bodies, agricultural machinery and packaging, and is highly competitive for survival in new environments, significantly inhibiting the growth of other plants and reducing biodiversity in invaded areas [10-12]. *Solanum rostratume* is highly adaptable and has a wide ecological range, and is able to grow in both arid and humid environments, with habitats consisting of wasteland, roadsides, overgrazed grasslands, disturbed areas, and other areas of the world. Its habitats include wastelands, roadsides, overgrazed grasslands, disturbed areas, abandoned land near villages, agricultural land, and around reservoirs. It has a high dispersal capacity, as the spines of its fruits attach to animals and humans, as well as agricultural machinery and packaging, facilitating dispersal [13].

## 3. Adaptive Mechanisms of *Solanum Rostratum*

### 3.1 Reproductive Characteristics of *Solanum Rostratum*

*Solanum rostratum* has thorns all over the plant. Healthy plants usually produce 12-32 florets, with each floret usually producing more than 12-22 flowers, and each berry produces 45-90 seeds, which is very reproducible, with the total seed production of the plant being 2,000-20,000 seeds. *Solanum rostratum* thrives optimally in sandy soils under warm climates. Under full sunlight conditions, the plants exhibit vigorous growth with larger fruits and higher seed yields. In contrast, insufficient light leads to reduced plant vigor and diminished seed production [11,14,15].

Most exotic species have a wide range of adaptations and a high invasive potential, and are able to establish dominant populations in new environments quickly [16]. Many exotic species are able to survive in a wide range of ecosystems, spanning the tropics, subtropics, warm temperate zones, and the temperate zone. Many exotic species can survive across tropical, subtropical, warm-temperate and temperate regions, and in a variety of ecosystems, with a wide range of invasive habitats [17]; some exotic species can survive in poor soils, and some are drought-resistant, shade-resistant, cold-resistant, temperature-resistant, and have a strong ability to resist pollution, and can flourish in large quantities once the conditions are suitable or improve [18].

### 3.2 Dormancy Characteristics of *Solanum Rostratum* Seeds

*Solanum rostratum* seeds have a mixed dormancy characteristic, mainly consisting of physical dormancy (the mechanical barrier effect of the seed coat) physiological dormancy (the presence of inhibitors of germination in the embryo), with low seed germination rate and long germination time, and maintain vitality for a time under harsh conditions. The seed coat of S. torvum is dense and thick, with poor water permeability and gas permeability, especially the cotyledon cap which forms a physical barrier to seed germination, limiting the proembryo from breaking through the cotyledon cap and seed coat [19-22]. Recently harvested mature seeds was only about 5%, and the germination time was long, requiring 20 days. After treatment with concentrated sulfuric acid 10 min, the seed germination rate could reach more than 50% after 3 days, which indicated that *Solanum rostratum* had physical dormancy. germination rate of seeds obtained from newly matured berries was 0, but after treatment with 0.6 mmol/L GA3, the germination rate of seeds reach 95%, which indicated that newly matured S. torvum seeds had physiological dormancy [23].

The germination rate of *Solanum rostratum* seeds is low, and the germination time is long. This characteristic is not conducive to the rapid and large-scale reproduction of its population in new habitats. However, the dense and thick seed coat can provide better protection for the embryo, allowing it to resist adverse environments and maintain vitality for a long time under harsh conditions. This characteristic is a dormancy mechanism for its long-term adaptation to the environment. Soil burial experiments show that when *Solanum rostratum* seeds are buried in non-cultivated soil at a depth of about 25 cm, the seeds still maintain vitality in silty clay in the 5th year and can still germinate in sandy loam in

 

the 17th year [24].

### 3.3 Genetic Properties of *Solanum Rostratum*

Invasive populations have reduced genetic diversity compared to their native populations. This is generally considered to be detrimental to the population [25]. However, in some cases, lower genetic diversity in a population can enhance the ability of an invasive species to compete and survive in a new habitat [26].

Morphological characters of *Solanum rostratum* show highly significant differences between populations. Such differences are clearly not due to environmental influences, but are probably caused by genetic differences in the seeds of different populations. This indicates that the alien species show strong adaptive capacity, which is related to their level of genetic differentiation in different habitats.

## 4. Mechanisms of Invasive Species Dispersal

### 4.1 Seed Dispersal Characteristics of *Solanum Rostratum*

Seed dispersal characteristics *Solanum rostratum* has a strong reproductive ability. The plant reproduces by seeds, and it has a long and numerous flowering time, with a flowering and fruiting period from June to October [12]. The aboveground part of the plant breaks off at the base of the stem in the fall, and the whole plant spreads its seeds by rolling in the wind, or by sticking the calyx of its thorns into the skin of animals, human clothes, agricultural equipment and packaging, or by spreading the seeds themselves by wind and water currents, or by mixing them with the seeds of other plants for long-distance spreading [1,13,15]. The seeds have a hard, dormant seed coat, which increases the survival rate of the seeds to a certain extent. Research has shown that buried seeds can still germinate when they are turned out of the ground during plowing.

### 4.2 Allelopathy

Allelopathy refers to the release of chemical substances into the environment by donor plants through stem and leaf volatilization, leaching, decomposition of apomictic material and root secretion, thus affecting the growth and development of the surrounding plants [11]. In ecosystems, plants release chemicals into the environment to affect their own growth and development or that of other organisms (including plants, microorganisms and animal receptors), this phenomenon is known as allelopathy, which is an adaptive mechanism formed by plants during long-term evolution, beneficial for maintaining an advantage in survival competition for the species [26].

*Solanum rostratum* is an annual herbaceous plant belonging to the Solanaceae family. It contains solanine, a naturally toxic compound, posing a potential threat to surrounding native plants [27]. The allelopathic substances in the invasive plant *Solanum rostratum* are primarily concentrated in the chloroform and n-butanol extracts of its stems and leaves, indicating they are moderate-to-high polarity compounds. These compounds are not present in its petroleum ether or aqueous extracts [28]. Current research on the allelopathic effects of *Solanum rostratum* is limited, and further studies are needed to isolate, extract, and analyze its allelochemical components.

### 4.3 Competitive Mechanisms of *Solanum Rostratum*

Competition between plants is divided into direct competition and indirect competition. Direct competition, also known as allelopathy, refers to a natural phenomenon in which, during their growth and development, change their surrounding micro-environment by releasing metabolites from their bodies, thus causing mutual exclusion or promotion among plants in the same growth environment. Ind competition refers to the competition for above-ground (light, heat) and below-ground resources (water, mineral nutrients) between adjacent plants, which is the ability of an individual to limit other individuals from obtaining resources in order to obtain resources.

*Solanum rostratum* is a malignant weed that has spread widely across the world. Currently, it is proliferating in China in an expanding manner. The plant itself contains the toxic substance solanine and exhibits allelopathic effects, which can harm surrounding plants and crops. Additionally, its strong reproductive and dispersal capabilities give it a competitive advantage.

### 4.4 Control Measures for *Solanum Rostratum*

Currently, there are three main methods for controlling *Solanum rostratum*: physical, chemical, and competitive replacement approaches. As one of the most common

 

methods for eradicating *Solanum rostratum*, physical removal has proven effective when timed correctly. Studies indicate that the weed grows slowly in its early stages but rapidly accelerates afterward, making pre-flowering removal the most efficient approach.

Long-term monitoring of infested areas helps track its growth patterns, enabling targeted eradication—particularly when plants are eliminated before seed maturation, which yields significant results. However, this method is labor-intensive and time-consuming, requiring repeated, multi-year efforts for full effectiveness. Consequently, large-scale implementation remains challenging [29,30]. Chemical removal is mainly a screening process for herbicides. The study showed that seven herbicides were effective in the control of *Solanum rostratum*, including paraquat, glyphosate, aminopyralid, triclopyr, flusulfanilamide, octanoyl bromobenzonitrile and chlorofluroxypyrifos. Among them, triclopyr is mainly used in non-cultivated land, flumetsulam is used in soybean and peanut fields, octylbromobenzonitrile, aminopyralid and chlorofluroxypyrifos are used in cornfields, and octylbromobenzonitrile and chlorofluroxypyrifos are used in wheat fields [29]. Competitive exclusion method is generally combined with physical control method. After the physical control method completely eradicates the yellow nutsedge, in order to prevent its re-inion, the plant alternative control can be adopted to increase the plant diversity of its habitat [31].

### 4.5 Potential for *Solanum Rostratum* Invasion

Although biological invasions are common in ecosystems, ecosystems are not subject to the same degree of invasion by exotic species, and some communities appear to be more susceptible to invasions by exotic species [32]. In recent years, China's high trade volume has resulted in a number of invasions of *Solanum rostratum*. Some non-native plants may have been brought into the country by wheels or people, and have begun to spread in the country because of their ability to reproduce and chemosensitize. Recent studies have shown that the relationship of disturbance to invasion is complex. Human activities can directly bring in exotic species. The role of disturbance is multifaceted, and excessive disturbance can reduce community biodiversity [33]. Invasive plant species pose significant challenges to natural ecosystems worldwide, with *Solanum rostratum* being one such widely distributed invasive plant that has garnered considerable attention in the ecological community for its impacts on natural habitats [34].

## 5. Historical Invasion Potential of *Solanum Rostratum*

*Solanum rostratum* as a malignant invasive weed, its invasion mechanism and reasons are investigated and studied. This can offer a theoretical foundation for further research on yellow nutsedge. The successful of yellow nutsedge might involve other invasion mechanisms, which require in-depth research:

(1) Adaptive evolution: Due to the ability of *Solanum rostratum* to adapt to a variety of habitats and to produce heritable variations in response to different environmental conditions, it can help it disperse and better adapt to the environment. For example, the same genotype shows differences in plant height, thorn density, and root length under different environmental conditions.

(2) Pollination characteristics: The efficient and flexible pollination of *Solanum rostratum* is achieved through mechanisms such as heteromorphic stamen division, deceptive attraction, and self incompatibility, which is an important basis for its successful invasion. This aspect should be further investigated to gain a deeper understanding of the reproductive characteristics of *Solanum rostratum* [34].

Synergistic Invasion: During the process of biological invasion, synergistic effects among alien species often exist, which means that several species cooperate with each other to invade. The invading species expand due to the loss of competitors, and both the alien species and its pathogens or parasites successfully invade [35,36]. Studies have shown that the invasion of Solanum laetum can spread nematodes, fungal species, and pests such as the potato beetle, may accelerate the invasion of *Solanum rostratum*.

## 6. Conclusion

In summary, the invasion process of *Solanum rostratum* involves multifaceted ecological interactions and adaptive strategies. Its successful colonization and establishment in new territories—followed by significant ecosystem impacts—result from the synergistic integration of multiple biological and

 

environmental factors.

The study of alien plant invasions is an important field in current ecology and environmental science, involving the diffusion mechanism, ecological impact and prevention and control strategies of invasive species. The research on alien plant invasions is transitioning from traditional ecological surveys to a comprehensive prevention and control system that combines remote sensing machine learning, and big data. Therefore, understanding the reasons why the yellow start thorn successfully becomes an invasive species is of great guiding significance for in-depth research on the invasion of the yellow start thorn, for predicting the range of *Solanum rostratum* invasion, and for taking appropriate measures to reduce the harm caused by the *Solanum rostratum* thorn species.

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